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The Determination of Organophosphorus Pesticides in Industrial and Municipal Wastewater: Method 622

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THE DETERMINATION OF ORGANOPHOSPHORUS PESTICIDES IN INDUSTRIAL AND MUNICIPAL WASTEWATER

Method 622

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16. ABSTRACT

This is a gas chromatographic (GC) method applicable to the determination of selected pesticides in municipal and industrial discharges as provided under 40CFR 136.1. A sample is solvent extracted with methylene chloride using a separatory funnel. The extract is concentrated and analyzed by GC using a flame photometric or phosphorus/nitrogen detector.

The compounds included in the method scope are: azinphos methyl, bolstar, chlorpyrifos, coumaphos, demeton, diazinon, dichlorvos, disulfoton, ethoprop, fensulfothion, fenthion, merphos, mevinphos, naled, parathion methyl, phorate, ronnel, stirophos, tokuthion, and trichloronate.

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IN INDUSTRIAL AND MUNICIPAL WASTEWATER

METHOD 622

1. Scope and Application

1.1 This method covers the determination of certain organophosphorus pesticides. The following parameters can be determined by this method:

Parameter	STORET No.	CAS No.
Azinphos methyl	39580	86-50-0
Bolstar	--	35400-43-2
Chlorpyrifos	--	2921-88-2
Chlorpyrifos methyl	--	5598-13-0
Coumaphos	81293	56-72-4
Demeton	39560	8065-48-3
Diazinon	39570	333-41-5
Dichlorvos	--	62-73-7
Disulfoton	39010	298-04-4
Ethoprop	--	13194-48-4
Fensulfothion	--	115-90-2
Fenthion	39016	55-38-9
Merphos	39019	150-50-5
Mevinphos	--	7786-34-7
Naled	--	300-76-5
Parathion methyl	39600	298-00-0
Phorate	39023	298-02-2
Ronnel	39357	299-84-3
Stirofos	--	961-11-5
Tokuthion	--	34643-46-4
Trichloronate	--	327-98-0

1.2 This is a gas chromatographic (GC) method applicable to the determination of the compounds listed above in industrial and municipal discharges as provided under 40 CFR 136.1. Any modification of this method beyond those expressly permitted, shall be considered a major modification subject to application and approval of alternate test procedures under 40 CFR 136.4 and 136.5.

1.3 The estimated method detection limit (MDL, defined in Section 15) for each parameter is listed in Table 1. The MDL for a specific

wastewater may differ from those listed, depending upon the nature of interferences in the sample matrix.

1.4 The sample extraction and concentration steps in this method are essentially the same as several others in the 600-method series. Thus, a single sample may be extracted to measure the parameters included in the scope of each of these methods. When cleanup is required, the concentration levels must be high enough to permit selecting aliquots, as necessary, in order to apply appropriate cleanup procedures. Under Gas Chromatography, the analyst is allowed the latitude to select chromatographic conditions appropriate for the simultaneous measurement of combinations of these parameters (see Section 12).

1.5 This method is restricted to use by or under the supervision of analysts experienced in the use of gas chromatography and in the interpretation of gas chromatograms. Each analyst must demonstrate the ability to generate acceptable results with this method using the procedure described in Section 8.2.

1.6 When this method is used to analyze unfamiliar samples for any or all of the compounds above, compound identifications should be supported by at least one additional qualitative technique. Section 14 provides gas chromatograph/mass spectrometer (GC/MS) criteria appropriate for the qualitative confirmation of compound identifications.

2. Summary of Method

2.1 A measured volume of sample, approximately 1-liter, is solvent extracted with 15% methylene chloride using a separatory funnel. The methylene chloride extract is dried and exchanged to hexane during concentration to a volume of 10 mL or less. Gas chromatographic conditions are described which permit the separation and measurement of the compounds in the extract by gas chromatography with a thermionic bead or flame photometric detector in the phosphorus mode.[1]

3. Interferences

3.1 Method interferences may be caused by contaminants in solvents, reagents, glassware and other sample processing apparatus that lead to discrete artifacts or elevated baselines in gas chromatograms. All reagents and apparatus must be routinely demonstrated to be free from interferences under the conditions of the analysis by running laboratory reagent blanks as described in Section 8.5.

3.1.1 Glassware must be scrupulously cleaned.[2] Clean all glassware as soon as possible after use by thoroughly rinsing with the last solvent used in it. Follow by washing with hot water and detergent and thorough rinsing with tap and reagent water. Drain dry, and heat in an oven or muffle

furnace at 400°C for 15 to 30 min. Do not heat volumetric ware. Thermally stable materials such as PCBs, might not be eliminated by this treatment. Thorough rinsing with acetone and pesticide quality hexane may be substituted for the heating. After drying and cooling, seal and store glassware in a clean environment to prevent any accumulation of dust or other contaminants. Store inverted or capped with aluminum foil.

3.1.2 The use of high purity reagents and solvents helps to minimize interference problems. Purification of solvents by distillation in all-glass systems may be required.

3.2 Matrix interferences may be caused by contaminants that are coextracted from the sample. The extent of matrix interferences will vary considerably from source to source, depending upon the nature and diversity of the industrial complex or municipality sampled. Unique samples may require special clean-up approaches or selective GC detectors to achieve the MDL listed in Table 1. Use of a flame photometric detector in the phosphorus mode will minimize interferences from materials that do not contain phosphorus. Elemental sulfur, however, may interfere with the determination of certain organophosphorus pesticides by flame photometric gas chromatography. A halogen specific detector (electrolytic conductivity or microcoulometric) is very selective for the halogen containing pesticides and has been shown to be effective in the analysis of wastewater for dichlorvos, naled and stirofos.

4. Safety

4.1 The toxicity or carcinogenicity of each reagent used in this method has not been precisely defined; however, each chemical compound must be treated as a potential health hazard. From this viewpoint, exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material data handling sheets should also be made available to all personnel involved in the chemical analysis. Additional references to laboratory safety are available and have been identified [3-5] for the information of the analyst.

5. Apparatus and Materials

5.1 Sampling equipment, for discrete or composite sampling.

5.1.1 Grab sample bottle - Amber borosilicate or flint glass, 1-liter or 1-quart volume, fitted with screw caps lined with TFE-fluorocarbon. Aluminum foil may be substituted for TFE if the sample is not corrosive. If amber bottles are not available, protect samples from light. The container and cap liner must be washed, rinsed with acetone or methylene

chloride, and dried before use to minimize contamination.

5.1.2 Automatic sampler (optional) - Must incorporate glass sample containers for the collection of a minimum of 250 mL. Sample containers must be kept refrigerated at 4°C and protected from light during compositing. If the sampler uses a peristaltic pump, a minimum length of compressible silicone rubber tubing may be used. Before use, however, the compressible tubing must be thoroughly rinsed with methanol, followed by repeated rinsings with reagent water to minimize the potential for contamination of the sample. An integrating flow meter is required to collect flow proportional composites.

5.2 Glassware (All specifications are suggested. Catalog numbers are included for illustration only.)

5.2.1 Separatory funnel - 2000-mL, with TFE-fluorocarbon stopcock, ground glass or TFE stopper.

5.2.2 Drying column - Chromatographic column 400 mm long x 19 mm ID with coarse fritted disc.

5.2.3 Concentrator tube, Kuderna-Danish - 10-mL, graduated (Kontes K-570050-1025 or equivalent). Calibration must be checked at the volumes employed in the test. Ground glass stopper is used to prevent evaporation of extracts.

5.2.4 Evaporative flask, Kuderna-Danish - 500-mL (Kontes K-570001-0500 or equivalent). Attach to concentrator tube with springs.

5.2.5 Snyder column, Kuderna-Danish - three-ball macro (Kontes K-503000-0121 or equivalent).

5.2.6 Vials - Amber glass, 10 to 15 mL capacity with TFE-fluorocarbon lined screw cap.

5.3 Boiling chips - approximately 10/40 mesh. Heat at 400°C for 30 min or Soxhlet extract with methylene chloride.

5.4 Water bath - Heated, with concentric ring cover, capable of temperature control (± 2°C). The bath should be used in a hood.

5.5 Balance - Analytical, capable of accurately weighing to the nearest 0.0001 g.

5.6 Gas chromatograph - Analytical system complete with gas chromatograph suitable for on-column injection and all required accessories including syringes, analytical columns, gases, detector and strip-chart recorder. A data system is recommended for measuring peak areas.

5.6.1 Columns - These columns were used to develop the method performance statements in Section 15. Alternate columns may be used in accordance with the provisions described in Section 12.1.

5.6.1.1 Column 1 - 180 cm long x 2 mm ID glass, packed with 5% SP-2401 on Supelcoport (100/120 mesh) or equivalent.

5.6.1.2 Column 2 - 180 cm long x 2 mm ID glass, packed with 3% SP-2401 on Supelcoport (100/120 mesh) or equivalent.

5.6.1.3 Column 3 - 50 cm long x 1/8 inch OD Teflon, packed with 15% SE-54 on Gas Chrom Q (80/100 mesh) or equivalent.

5.6.2 Detector - Thermionic bead or flame photometric in the phosphorus mode. These detectors have proven effective in the analysis of wastewaters for the parameters listed in the scope and were used to develop the method performance statements in Section 15. Alternative detectors, including a mass spectrometer, may be used in accordance with the provisions described in Section 12.1.

6. Reagents

6.1 Reagent water - Reagent water is defined as a water in which an interferent is not observed at the method detection limit of each parameter of interest.

6.2 Acetone, hexane, methylene chloride - Pesticide quality or equivalent.

6.3 Sodium sulfate - (ACS) Granular, anhydrous. Heat treat in a shallow tray at 400°C for a minimum of 4 h to remove phthalates and other interfering organic substances. Alternatively, heat 16 h at 450-500°C in a shallow tray or Soxhlet extract with methylene chloride for 48 h.

6.5 Stock standard solutions (1.00 µg/µL) - Stock standard solutions may be prepared from pure standard materials or purchased as certified solutions.

6.5.1 Prepare stock standard solutions by accurately weighing approximately 0.0100 g of pure material. Dissolve the material in pesticide quality hexane or other suitable solvent and dilute to volume in a 10-mL volumetric flask. Larger volumes may be used at the convenience of the analyst. If compound purity is certified at 96% or greater, the weight may be used without correction to calculate the concentration of the stock standard. Commercially prepared

stock standards may be used at any concentration if they are certified by the manufacturer or by an independent source.

6.5.2 Transfer the stock standard solutions into TFE-fluorocarbon sealed screw cap vials. Store at 4°C and protect from light. Frequently check stock standard solutions for signs of degradation or evaporation, especially just prior to preparing calibration standards from them.

6.6.3 Stock standard solutions must be replaced after six months or sooner if comparison with check standards indicates a problem.

7. Calibration

7.1 Establish gas chromatographic operating parameters equivalent to those indicated in Table 1. The gas chromatographic system may be calibrated using either the external standard technique (Section 7.2) or the internal standard technique (Section 7.3).

7.2 External standard calibration procedure:

7.2.1 For each parameter of interest, prepare calibration standards at a minimum of three concentration levels by adding accurately measured volumes of one or more stock standards to a volumetric flask and diluting to volume with hexane or other suitable solvent. One of the external standards should be representative of a concentration near, but above, the method detection limit. The other concentrations should correspond to the range of concentrations expected in the sample concentrates or should define the working range of the detector.

7.2.2 Using injections of 1 to 5 µL of each calibration standard, tabulate peak height or area responses against the mass injected. The results can be used to prepare a calibration curve for each parameter. Alternatively, the ratio of the response to the mass injected, defined as the calibration factor (CF), may be calculated for each parameter at each standard concentration. If the relative standard deviation of the calibration factor is less than 10% over the working range, the average calibration factor can be used in place of a calibration curve.

7.2.3 The working calibration curve or calibration factor must be verified on each working shift by the measurement of one or more calibration standards. If the response for any parameter varies from the predicted response by more than ±10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve or calibration factor must be prepared for that parameter.

7.3 Internal standard calibration procedure. To use this approach, the analyst must select one or more internal standards similar in analytical behavior to the compounds of interest. The analyst must further demonstrate that the measurement of the internal standard is not affected by method or matrix interferences. Due to these limitations, no internal standard applicable to all samples can be suggested.

7.3.1 Prepare calibration standards at a minimum of three concentration levels for each parameter of interest by adding volumes of one or more stock standards to a volumetric flask. To each calibration standard, add a known constant amount of one or more internal standards, and dilute to volume with hexane or other suitable solvent. One of the standards should be representative of a concentration near, but above, the method detection limit. The other concentrations should correspond to the range of concentrations expected in the sample concentrates, or should define the working range of the detector.

7.3.2 Using injections of 1 to 5 µL of each calibration standard, tabulate the peak height or area responses against the concentration for each compound and internal standard. Calculate response factors (RF) for each compound as follows:

$$RF = (A_s C_{is})/(A_{is} C_s)$$

where:

A_s = Response for the parameter to be measured.
A_{is} = Response for the internal standard.
C_{is} = Concentration of the internal standard in µg/L.
C_s = Concentration of the parameter to be measured in µg/L.

If the RF value over the working range is constant, less than 10% relative standard deviation, the RF can be assumed to be invariant and the average RF may be used for calculations. Alternatively, the results may be used to plot a calibration curve of response ratios, A_s/A_{is} against RF.

7.3.3 The working calibration curve or RF must be verified on each working shift by the measurement of one or more calibration standards. If the response for any parameter varies from the predicted response by more than ±10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve must be prepared for that compound.

7.4 Before using any cleanup procedure, the analyst must proces[illegible] series of calibration standards through the procedure to validate elution patterns and the absence of interference from the reagents.

8. Quality Control

8.1 Each laboratory using this method is required to operate a formal quality control program. The minimum requirements of this program consist of an initial demonstration of laboratory capability and the analysis of spiked samples as a continuing check on performance. The laboratory is required to maintain performance records to define the quality of data that is generated.

8.1.1 Before performing any analyses, the analyst must demonstrate the ability to generate acceptable accuracy and precision with this method. This ability is established as described in Section 8.2.

8.1.2 In recognition of the rapid advances occurring in chromatography, the analyst is permitted certain options to improve the separations or lower the cost of measurements. Each time such modifications to the method are made, the analyst is required to repeat the procedure in Section 8.2.

8.1.3 The laboratory must spike and analyze a minimum of 10% of all samples to monitor continuing laboratory performance. This procedure is described in Section 8.4.

8.2 To establish the ability to generate acceptable accuracy and precision, the analyst must perform the following operations.

8.2.1 Select a representative spike concentration for each compound to be measured. Using stock standards, prepare a quality control check sample concentrate in acetone 1000 times more concentrated than the selected concentrations.

8.2.2 Using a pipet, add 1.00 mL of the check sample concentrate to each of a minimum of four 1000-mL aliquots of reagent water. A representative wastewater may be used in place of the reagent water, but one or more additional aliquots must be analyzed to determine background levels, and the spike level must exceed twice the background level for the test to be valid. Analyze the aliquots according to the method beginning in Section 10.

8.2.3 Calculate the average percent recovery (R), and the standard deviation of the percent recovery (s), for the results. Wastewater background corrections must be made before R and s calculations are performed.

8.2.4 Using the appropriate data from Table 2, determine the recovery and single operator precision expected for the method, and compare these results to the values calculated in Section 8.2.3. If the data are not comparable, review potential problem areas and repeat the test.

8.3 The analyst must calculate method performance criteria and define the performance of the laboratory for each spike concentration and parameter being measured.

8.3.1 Calculate upper and lower control limits for method performance as follows:

Upper Control Limit (UCL) = R + 3 s

Lower Control Limit (LCL) = R - 3 s

where R and s are calculated as in Section 8.2.3. The UCL and LCL can be used to construct control charts[6] that are useful in observing trends in performance.

8.3.2 The laboratory must develop and maintain separate accuracy statements of laboratory performance for wastewater samples. An accuracy statement for the method is defined as R ± s. The accuracy statement should be developed by the analysis of four aliquots of wastewater as described in Section 8.2.2, followed by the calculation of R and s. Alternatively, the analyst may use four wastewater data points gathered through the requirement for continuing quality control in Section 8.4. The accuracy statements should be updated regularly.[6]

8.4 The laboratory is required to collect in duplicate a portion of their samples to monitor spike recoveries. The frequency of spiked sample analysis must be at least 10% of all samples or one spiked sample per month, whichever is greater. One aliquot of the sample must be spiked and analyzed as described in Section 8.2. If the recovery for a particular parameter does not fall within the control limits for method performance, the results reported for that parameter in all samples processed as part of the same set must be qualified as described in Section 13.3. The laboratory should monitor the frequency of data so qualified to ensure that it remains at or below 5%.

8.5 Before processing any samples, the analyst must demonstrate through the analysis of a 1-liter aliquot of reagent water that all glassware and reagents interferences are under control. Each time a set of samples is extracted or there is a change in reagents, a laboratory reagent blank must be processed as a safeguard against laboratory contamination.

8.6 It is recommended that the laboratory adopt additional quality assurance practices for use with this method. The specific practices that are most productive depend upon the needs of the laboratory and the nature of the samples. Field duplicates may be analyzed to monitor the precision of the sampling technique. When doubt exists over the identification of a peak on the chromatogram, confirmatory techniques such as gas chromatography with a dissimilar column, specific element detector, or mass spectrometer must be used. Whenever possible, the laboratory should perform

analysis of quality control materials and participate in relevant performance evaluation studies.

9. Sample Collection, Preservation, and Handling

9.1 Grab samples must be collected in glass containers. Conventional sampling practices[7] should be followed; however, the bottle must not be prerinsed with sample before collection. Composite samples should be collected in refrigerated glass containers in accordance with the requirements of the program. Automatic sampling equipment must be as free as possible of plastic and other potential sources of contamination.

9.2 The samples must be iced or refrigerated at 4°C from the time of collection until extraction.

9.3 All samples must be extracted within seven days and completely analyzed within 40 days of extraction.

10. Sample Extraction

10.1 Mark the water meniscus on the side of the sample bottle for later determination of sample volume. Pour the entire sample into a 2-liter separatory funnel.

10.2 Add 60 mL methylene chloride to the sample bottle, seal, and shake 30 s to rinse the inner walls. Transfer the solvent to the separatory funnel and extract the sample by shaking the funnel for 2 min with periodic venting to release excess pressure. Allow the organic layer to separate from the water phase for a minimum of 10 min. If the emulsion interface between layers is more than one third the volume of the solvent layer, the analyst must employ mechanical techniques to complete the phase separation. The optimum technique depends upon the sample, but may include stirring, filtration of the emulsion through glass wool, centrifugation, or other physical methods. Collect the methylene chloride extract in a 250-mL Erlenmeyer flask.

10.3 Add a second 60-mL volume of methylene chloride to the sample bottle and repeat the extraction procedure a second time, combining the extracts in the Erlenmeyer flask. Perform a third extraction in the same manner.

10.4 Assemble a Kuderna-Danish (K-D) concentrator by attaching a 10-mL concentrator tube to a 500-mL evaporative flask. Other concentration devices or techniques may be used in place of the K-D if the requirements of Section 8.2 are met.

10.5 Pour the combined extract through a drying column containing about 10 cm of anhydrous sodium sulfate, and collect the extract in the K-D concentrator. Rinse the Erlenmeyer flask and column with 20 to 30 mL of methylene chloride to complete the quantitative transfer.

10.6 Add 1 or 2 clean boiling chips to the evaporative flask and attach a three-ball Snyder column. Prewet the Snyder column by adding about 1 mL methylene chloride to the top. Place the K-D apparatus on a hot water bath, 60 to 65°C, so that the concentrator tube is partially immersed in the hot water, and the entire lower rounded surface of the flask is bathed with hot vapor. Adjust the vertical position of the apparatus and the water temperature as required to complete the concentration in 15 to 20 min. At the proper rate of distillation, the balls of the column will actively chatter but the chambers will not flood with condensed solvent. When the apparent volume of liquid reaches 1 mL, remove the K-D apparatus and allow it to drain and cool for at least 10 min.

10.7 Increase the temperature of the hot water bath to about 80°C. Momentarily remove the Snyder column, add 50 mL of hexane and a new boiling chip and reattach the Snyder column. Pour about 1 mL of hexane into the top of the Snyder column and concentrate the solvent extract as before. Elapsed time of concentration should be 5 to 10 min. When the apparent volume of liquid reaches 1 mL, remove the K-D apparatus and allow it to drain and cool for at least 10 min.

10.8 Remove the Snyder column and rinse the flask and its lower joint into the concentrator tube with 1 to 2 mL of hexane and adjust the volume to 10 mL. A 5-mL syringe is recommended for this operation. Stopper the concentrator tube and store refrigerated if further processing will not be performed immediately. If the extracts will be stored longer than two days, they should be transferred to TFE-fluorocarbon-sealed screw-cap vials. If the sample extract requires no further cleanup, proceed with gas chromatographic analysis. If the sample requires cleanup, proceed to Section 11.

10.9 Determine the original sample volume by refilling the sample bottle to the mark and transferring the water to a 1000-mL graduated cylinder. Record the sample volume to the nearest 5 mL.

11. Cleanup and Separation

11.1 Cleanup procedures may not be necessary for a relatively clean sample matrix and were not required for the analysis of the wastewaters reported in Section 15. If particular circumstances demand the use of a cleanup procedure, the analyst must determine the elution profile and demonstrate that the recovery of each compound of interest for the cleanup procedure is no less than 85%.

12. Gas Chromatography

12.1 Table 1 summarizes the recommended operating conditions for the gas chromatograph. Included in this table are estimated retention times and method detection limits that can be achieved by this method. Naled is partially converted to dichlorvos on GC Columns 1 and 2 but not on Column 3. Therefore, if naled is to be measured

in the sample, GC analysis for dichlorvos and naled must be performed using Column 3. Examples of the separations achieved are shown in Figures 1 to 4. Other packed columns, chromatographic conditions, or detectors may be used if the requirements of Section 8.2 are met. Capillary (open-tubular) columns may also be used if the relative standard deviations of responses for replicate injections are demonstrated to be less than 6% and the requirements of Section 8.2 are met.

12.2 Calibrate the system daily as described in Section 7.

12.3 If the internal standard approach is being used, add the internal standard to sample extracts immediately before injection into the instrument. Mix thoroughly.

12.4 Inject 1 to 5 µL of the sample extract using the solvent-flush technique.[8] Record the volume injected to the nearest 0.05 µL, and the resulting peak size in area or peak height units. An automated system that consistently injects a constant volume of extract may also be used.

12.5 The width of the retention time window used to make identifications should be based upon measurements of actual retention time variations of standards over the course of a day. Three times the standard deviation of a retention time can be used to calculate a suggested window size for a compound. However, the experience of the analyst should weigh heavily in the interpretation of chromatograms.

12.6 If the response for the peak exceeds the working range of the system, dilute the extract and reanalyze.

12.7 If the measurement of the peak response is prevented by the presence of interferences, cleanup is required.

13. Calculations

13.1 Determine the concentration of individual compounds in the sample.

13.1.1 If the external standard calibration procedure is used, calculate the amount of material injected from the peak response using the calibration curve or calibration factor in Section 7.2.2. The concentration in the sample can be calculated as follows:

$$\text{Concentration, } \mu g/L = \frac{(A)(V_t)}{(V_i)(V_s)}$$

where:

A = Amount of material injected, in nanograms.
V_i = Volume of extract injected in µL.
V_t = Volume of total extract in µL.
V_s = Volume of water extracted in mL.

13.1.2 If the internal standard calibration procedure was used, calculate the concentration in the sample using the response factor (RF) determined in Section 7.3.2 as follows:

$$\text{Concentration, } \mu g/L = \frac{(A_s)(I_s)}{(A_{is})(RF)(V_o)}$$

where:

A_s = Response for the parameter to be measured.
A_{is} = Response for the internal standard.
I_s = Amount of internal standard added to each extract in µg.
V_o = Volume of water extracted, in liters.

13.2 Report results in micrograms per liter without correction for recovery data. When duplicate and spiked samples are analyzed, report all data obtained with the sample results.

13.3 For samples processed as part of a set where the laboratory spiked sample recovery falls outside of the control limits in Section 8.3, data for the affected parameters must be labeled as suspect.

14. GC/MS Confirmation

14.1 It is recommended that GC/MS techniques be judiciously employed to support qualitative compound identifications made with this method. The mass spectrometer should be capable of scanning the mass range from 35 amu to a mass 50 amu above the molecular weight of the compound. The instrument must be capable of scanning the mass range at a rate to produce at least 5 scans per peak but not to exceed 7 s per scan utilizing a 70 V (nominal) electron energy in the electron impact ionization mode. A GC to MS interface constructed of all-glass or glass-lined materials is recommended. A computer system should be interfaced to the mass spectrometer that allows the continuous acquisition and storage on machine readable media of all mass spectra obtained throughout the duration of the chromatographic program.

14.2 Gas chromatographic columns and conditions should be selected for optimum separation and performance. The conditions selected must be compatible with standard GC/MS operating practices. Chromatographic tailing factors of less than 5.0 must be achieved.[9]

14.3 At the beginning of each day that confirmatory analyses are to be performed, the GC/MS system must be checked to see that all decafluorotriphenyl phosphine (DFTPP) performance criteria are achieved.[10]

14.4 To confirm an identification of a compound, the background corrected mass spectrum of the compound must be obtained from the sample extract and compared with a mass spectrum from a stock or calibration standard analyzed under the same chromatographic

conditions. It is recommended that at least 25 nanograms of material be injected into the GC/MS. The criteria below must be met for qualitative confirmation.

14.4.1 All ions that are present above 10% relative abundance in the mass spectrum of the standard must be present in the mass spectrum of the sample with agreement to plus or minus 10%. For example, if the relative abundance of an ion is 30% in the mass spectrum of the standard, the allowable limits for the relative abundance of that ion in the mass spectrum for the sample would be 20% to 40%.

14.4.2 The retention time of the compound in the sample must be within 6 seconds of the same compound in the standard solution.

14.4.3 Compounds that have very similar mass spectra can be explicitly identified by GC/MS only on the basis of retention time data.

14.5 Where available, chemical ionization mass spectra may be employed to aid in the qualitative identification process.

14.6 Should these MS procedures fail to provide satisfactory results, additional steps may be taken before reanalysis. These may include the use of alternate packed or capillary GC columns or additional cleanup (Section 11).

15. Method Performance

15.1 The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero.[11] The MDL concentrations listed in Table 1 were estimated from the response of the detector to each compound. The estimate is based upon the amount of material required to yield a signal five times the GC background noise, assuming a 5-µL injection from a 10-mL final extract of a 1-liter sample.

15.2 In a single laboratory (West Cost Technical Services, Inc.), using effluents from pesticide manufacturers and publicly owned treatment works (POTW), the average recoveries presented in Table 2 were obtained.[1] The standard deviations of the percent recoveries of these measurements are also included in Table 2.

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TABLE 1

CHROMATOGRAPHIC CONDITIONS AND ESTIMATED METHOD DETECTION LIMITS

Parameter	GC Column	Retention Time (Min)	Estimated MDL (µg/L)
Demeton	1a	1.16, 2.53	0.25
Phorate	1a	1.43	0.15
Disulfoton	1a	2.10	0.20
Trichloronate	1a	2.94	0.15
Fenthion	1a	3.12	0.10
Tokuthion	1a	3.40	0.5
Bolstar	1a	4.23	0.15
Fensulfothion	1a	6.41	1.5
Azinphos methyl	1a	6.80	1.5
Coumaphos	1a	11.6	1.5
Dichlorvos	1b	0.8	0.1
Mevinphos	1b	2.41	0.3
Stirofos	1b	8.52	5.0
Ethoprop	2	3.02	0.25
Parathion methyl	2	3.37	0.3
Ronnel	2	5.57	0.3
Chlorpyrifos methyl	2	5.72	0.3
Chlorpyrifos	2	6.16	0.3
Merphos	2	7.45	0.25
Diazinon	2	7.73	0.6
Dichlorvos	3	1.50	0.1
Naled	3	3.28	0.1
Stirofos	3	5.51	5.0

Column 1a Conditions: Supelcoport (100/120 mesh) coated with 5% SP-2401 packed in a 180 cm long x 2 mm ID glass column with helium carrier gas at a flow rate of 30 mL/min. Column temperature, programmed: initial 150°C, hold for 1 min, then program at 25°C/min to 220°C and hold. A flame photometric detector was used with this column to estimate the MDL.

Column 1b Conditions: Same as Column 1a, except nitrogen carrier gas at a flow rate of 30 ml/min. Temperature, programmed: initial 170°C, hold 2 min, then program at 20°C/min to 220°C and hold.

Column 2 Conditions: Supelcoport (100/120 mesh) coated with 3% SP-2401 packed in a 180 cm long x 2 mm ID glass column with helium carrier gas at a flow rate of 25 mL/min. Column temperature, programmed, initial 170°C, hold for 7 min, then program at 10°C/min to 250°C and hold. A thermionic bead detector was used with this column to estimate the MDL.

TABLE 1. (Continued)

Column 3 Conditions: Gas Chrom Q (100/120 mesh) coated with 15% SE-54 packed in a 50 cm long x 1/8 in. OD Teflon column with nitrogen carrier gas at a flow rate of 30 mL/min. Temperature, programmed: initial 100°C, then program immediately at 25°C/min to 200°C and hold. An electrolytic detector in the halogen mode was used with this column to estimate the MDL.

TABLE 2

SINGLE OPERATOR ACCURACY AND PRECISION

Parameter	Average Percent Recovery	Standard Deviation (%)	Spike Range (µg/L)	Number of Analyses	Matrix Types
Azinphos methyl	72.7	18.8	21-250	17	3
Bolstar	64.6	6.3	4.9-46	17	3
Chlorpyrifos	98.3	5.5	1.0-50.5	18	3
Coumaphos	109.0	12.7	25-225	17	3
Demeton	67.4	10.5	11.9-314	17	3
Diazinon	67.0	6.0	5.6	7	1
Dichlorvos	72.1	7.7	15.6-517	16	3
Disulfoton	81.9	9.0	5.2-92	17	3
Ethoprop	100.5	4.1	1.0-51.5	18	3
Fensulfothion	94.1	17.1	23.9-110	17	3
Fenthion	68.7	19.9	5.3-64	17	3
Merphos	120.7	7.9	1.0-50	18	3
Mevinphos	56.5	7.8	15.5-520	16	3
Naled	78.0	8.1	25.8-294	16	3
Parathion methyl	96.0	5.3	0.5-500	21	3
Phorate	62.7	8.9	4.9-47	17	3
Ronnel	99.2	5.6	1.0-50	18	3
Stirofos	66.1	5.9	30.3-505	16	3
Tokuthion	64.6	6.8	5.3-64	17	3
Trichloronate	105.0	18.6	20	3	1

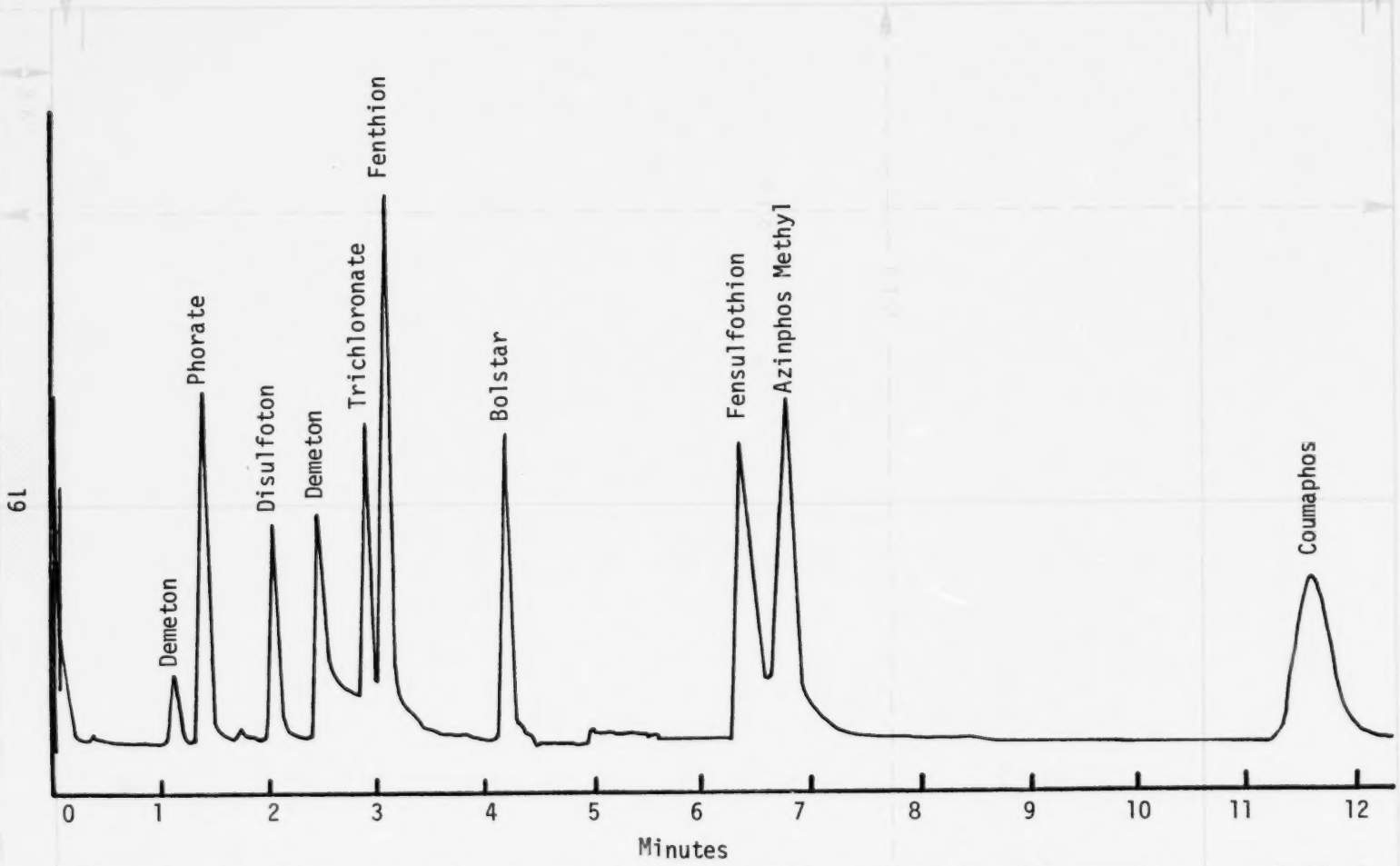

Figure 1. Gas chromatogram of organophosphorus pesticides on Column 1a. For conditions, see Table 1.

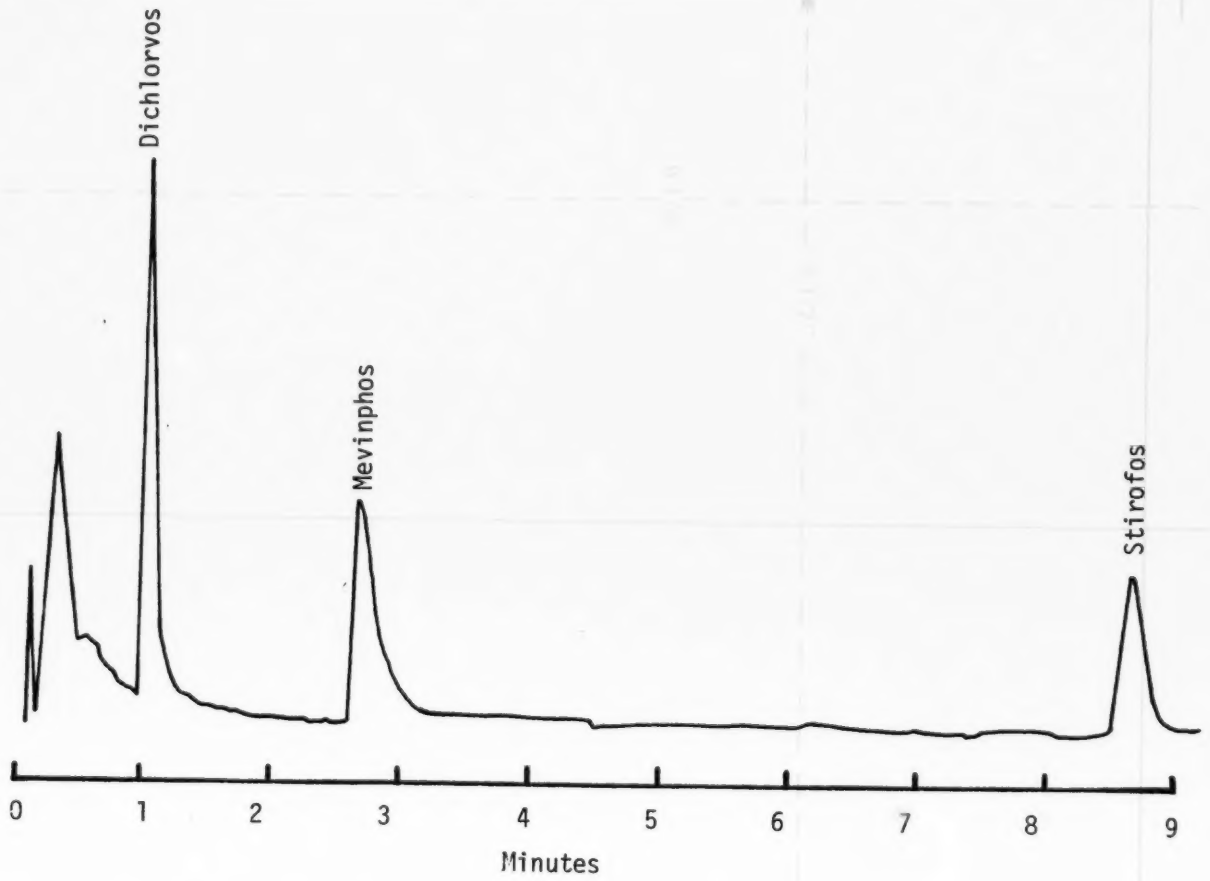

Figure 2. Gas chromatogram of organophosphorus pesticides on Column 1b. For conditions, see Table 1.

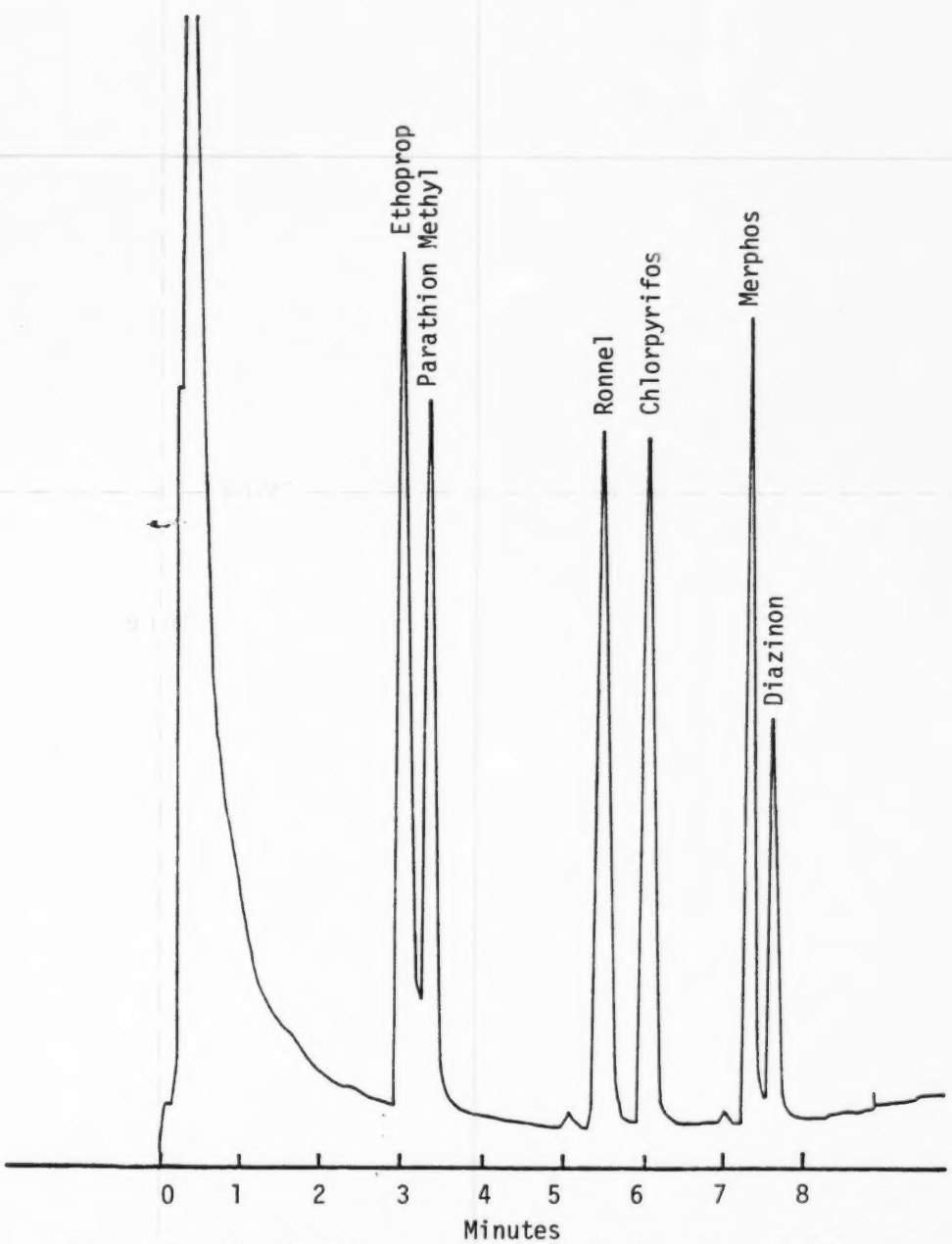

Figure 3. Gas chromatogram of organophosphorus pesticides on Column 2. For conditions, see Table 1.

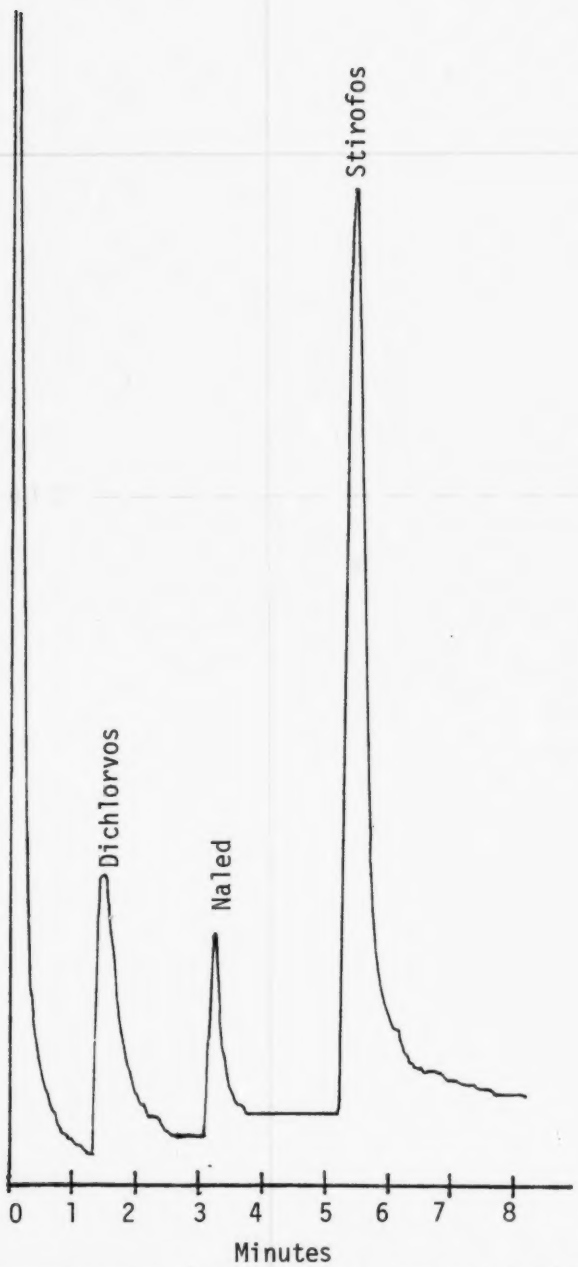

Figure 4. Gas chromatogram of organophosphorus pesticides on Column 3. For conditions, see Table 1.